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**FACTOR ANALYTIC REDUCTION OF THE
CAROTID-CARDIAC BAROREFLEX PARAMETERS**

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ABSTRACT

Nine carotid-cardiac baroreflex parameters were measured on 30 middle aged human males and subsequently factored in an effort to determine the underlying dimensionality of the parameters. The results indicated that the variation in the nine variables could be explained in four dimensions with only a seven percent loss of information.

SUMMARY

An accepted method for measuring the responsiveness of the carotid-cardiac baroreflex to arterial pressure changes is to artificially stimulate the baroreceptors in the neck. This is accomplished by using a pressurized neck cuff which constricts and distends the carotid artery and subsequently stimulates the baroreceptors. Nine physiological responses to this type of stimulation are quantified and used as indicators of the baroreflex.

Thirty male humans between the ages 27 and 46 underwent the carotid-cardiac baroreflex test. The data for the nine response parameters were analyzed by principle component factor analysis. The results of this analysis indicated that 93 percent of the total variance across all nine parameters could be explained in four dimensions. Examination of the factor loadings following an orthogonal rotation of the principle components indicated four well defined dimensions. The first two dimensions reflected location points for R-R interval and carotid distending pressure respectively. The third dimension was composed of measures reflecting the gain of the reflex. The fourth dimension was the ratio of the resting R-R interval to R-R interval during simulated hypertension.

The data suggests that the analysis of all nine baroreflex parameters is redundant and future analyses should be performed on an unweighted linear composite of the variables that make up each of the four underlying dimensions. An alternative to an unweighted composite would be the selection of one parameter from each of the four principle components.

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I. INTRODUCTION

The carotid baroreceptors are afferent arterial pressure receptors located in the walls of the carotid artery. These receptors respond to changes in arterial blood pressure and initiate various autonomic responses in order to maintain blood pressure and perfusion to the brain (1). The carotid baroreflex responds to these baroreceptors by altering heart rate to compensate for increases or decreases in arterial pressure. It is believed that orthostatic hypotension results when this reflex mechanism is attenuated (2). The symptoms of this condition include light headiness and in the extreme case, fainting (intolerance).

Astronauts who have been exposed to microgravity usually experience some degree of orthostatic hypotension after returning to a one G environment (3). It has been hypothesized that one of the major reason this occurs is due to a loss of the responsiveness of the baroreflex (2). The reflex is believed to be impaired during space flight since cranial blood flow is not challenged by the force of gravity.

An accepted method for evaluating the responsiveness of the carotid-cardiac baroreflex involves the use of a pressure cuff which is placed around the neck providing an artificial stimulus to the carotid artery (4). When negative pressure is applied, the carotid artery distends providing a high pressure stimulus (hypertension) to the baroreceptors. A low pressure stimulus (hypotension) is provided when a positive pressure is applied and the carotid artery is constricted. Sequential changes in pressure are compared to changes in beat-to-beat (R-R) interval providing an index of baroreceptor responsiveness. The responsiveness is quantified by nine variables which characterize the relationship between neck cuff pressure and R-R interval.

The nine measures of baroreceptor responsiveness were chosen based on physiological considerations. Their psychometric properties have only been evaluated on a limited basis (5). One such psychometric property is redundancy. It's possible that these nine measures can be expressed in fewer than nine dimensions with only minimal loss of information. If this were the case, greater efficiency in data collection and experimental analysis would be possible. It is therefore the purpose of this study to evaluate the intercorrelation structure of these nine variables and if possible, explain this structure in fewer than nine dimensions with a minimal loss of information.

II. METHODS

2.1 Subjects

Thirty healthy nonsmoking normotensive men between the ages of 27 and 46 gave written informed consent for the baroreflex test. Selection of subjects was based on the results of a clinical screening comprised of a detailed medical history, physical examination, urinalysis, complete blood count and chemistry, glucose tolerance test, chest X-ray, resting and treadmill electrocardiograms, and psychological evaluation. None of the subjects were taking prescription medication at the time of the study.

2.2 Experimental

Prior to testing and data collection, each subject was given an explanation of the baroreflex testing procedure and familiarized with the protocol. Carotid-cardiac baroreflex stimulus was delivered via a computer controlled motor driven bellows which provided pressure steps to a Silastic neck chamber. During held expiration, a pressure of about 40 mmHg was delivered to the chamber and held for about 5 seconds. Then, with the next R wave (heartbeat), the pressure sequentially stepped to about 25, 10, -5, -20, -35, -50, and -65 mmHg followed by a return to ambient pressure. Pressure steps were triggered by R-waves so that neck chamber pressure changes were superimposed upon naturally occurring carotid pulses. During each testing session the stimulus sequence was applied seven times and the data averaged for each subject. Subjects mean R-R interval for each pressure step was plotted against carotid distending pressure (resting systolic blood pressure minus neck chamber pressure) to produce a carotid-cardiac baroreceptor response function (Figure 1). Nine characteristics (parameters) of this response function were calculated and used for statistical analysis.

2.2.1 BAROREFLEX PARAMETERS. The nine baroreflex parameters are listed below and illustrated in Figure 1.

- (1) Minimum R-R Interval
- (2) Maximum R-R Interval
- (3) R-R Interval at Baseline
- (4) Range of the R-R Interval
- (5) Maximum Slope of the Response Function
- (6) Minimum Carotid Distending Pressure
- (7) Maximum Carotid Distending Pressure
- (8) Carotid Distending Pressure at Maximum Slope
- (9) Ratio of Resting R-R Interval Minus Minimum R-R Interval to R-R Range

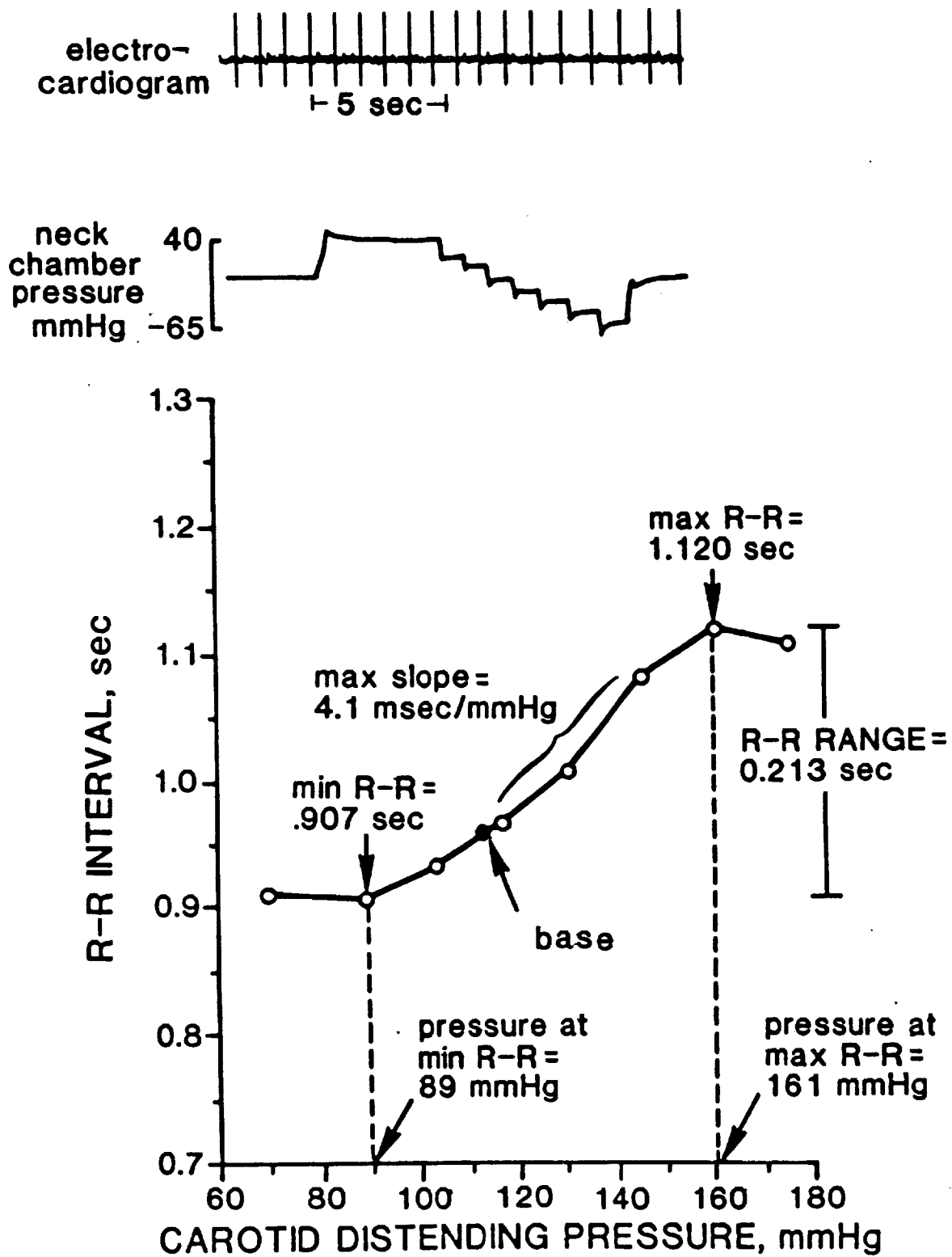


Figure 1. Baroreflex Response Function

Maximum slope was determined by least squares estimation of every set of three consecutive points on the response function. The slope estimate taken from the segment with the steepest slope was retained for statistical analysis. The carotid distending pressure at maximum slope was the point halfway between the pressures which defined the maximum slope.

2.3 Statistical

The 30 subject by nine variable data matrix was subjected to principle component analysis followed by an orthogonal rotation (varimax) of the initially extracted components. The number of components was determined by the solution which produced a simple structure of the factor loadings with a minimum number of factors needed to account for a majority of the variance in the nine parameters.

III. RESULTS AND DISCUSSION

Evaluation of the eigenvalues from the unrotated principle components, percent of explained variance, and rotated factor loadings indicated that a four factor solution was the most parsimonious. The four factor solution explained 92.5 of the of the variance in the original nine variables, and had a well defined (simple) structure. Table I presents the rotated factor loadings, post rotation eigenvalues and percent of explained variance for the four factor solution.

Table I. Rotated Factor Pattern

Parameter	Factor I	Factor II	Factor III	Factor IV
(1) RRMIN	.970*	-.137	-.071	-.169
(2) RRMAX	.921*	-.093	.340	-.151
(3) RRBASE	.968*	-.210	.015	.078
(4) RRRANG	.088	.075	.978*	.008
(5) MAXSLP	.058	-.187	.955*	.006
(6) CDPMIN	-.288	.791*	-.190	-.027
(7) CDPMAX	-.150	.887*	-.036	-.029
(8) CDPSLP	-.004	.896*	.075	-.265
(9) RRRATO	-.139	-.206	.015	.965*
Eigenvalue	2.86	2.37	2.03	1.06
% Variance	31.78	26.33	22.56	11.78
Cum % Var.	31.78	58.11	80.67	92.45

Interpretation of the factors seems relatively straight forward and makes good theoretical sense. Factor I is a location factor for R-R interval. It reflects the position of the baroreflex function on the y-axis. Factor II is the location factor for carotid distending pressure. It reflects the position of the baroreflex function on the x-axis. Factor III is a gain factor reflecting the change or responsiveness of the reflex. And factor IV is a single variable reflecting the percentage of the R-R range falling below the baseline point.

Since the factor loadings for this four factor solution are either very high or very low, a single variable from each factor can be used to account for the factor variance in lieu of an unweighted linear composite such as a sum. Selection of this one variable from each factor group is probably best left to the researcher. Previous research has indicated that the test-retest reliabilities for baseline R-R interval and maximum slope are slightly higher than the other possible factor representatives for factors I and III respectively (5). If carotid distending pressure were measured at baseline, this parameter would reduce to resting systolic blood pressure and provide a simpler measure of location on the x-axis. R-R ratio is a unique variable measuring the percent of the reflex function below the baseline point. Thus the only "true" baroreflex parameters are maximum slope and R-R ratio since factor I reflects heart rate and factor II reflects systolic pressure.

Certainly the slope of the reflex function is the best indicator of baroreflex responsiveness. Although the reliability of this parameter is already quit high (.92) (5), it could probably be improved by using all of the data points between minimum R-R interval and maximum R-R interval with very little change in the value of the parameter. This is true given the near linear response function for the baroreflex. When all the data points are used to calculating slope, the slope will be more stable even if one or two points tend to be extreme or out of range. In fact, the current calculation of maximum slope tends to seek out these extreme values. The practice of using the average of seven trials does smooth out the effects of possible outlying values.

IV. CONCLUSIONS

Researchers measuring the carotid-cardiac baroreflex need not measure or analyze all nine of the parameters calculated from the baroreflex response function. Nearly all of the variance in the original nine parameters can be accounted for by baseline R-R interval, a measure of carotid distending pressure, maximum or full slope of the response function, and the operational point (R-R ratio).

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